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AN ANALYSIS OF THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS AT THE GRADE ELEVEN LEVEL

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "An Analysis of the Effectiveness of Programmed Instruction in Mathematics at the Grade Eleven Level," submitted by John Mazurek in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

The purpose of this study was to gather information that could be used as a basis for evaluating the relative effectiveness of two methods of teaching logarithms to students registered in Mathematics 20.

In April, 1965, the Cooperative Intermediate Algebra (Quadratics and Beyond) Test, Form Y was administered to ten classes of Mathematics 20 students in the Edmonton (RC) Separate School system. Using a method of random selection, five classes were taught logarithms in the conventional classroom manner and the other classes were taught by the method of programmed instruction. When the unit of work was completed the Cooperative Intermediate Algebra (Quadratics and Beyond) Test, Form Z was administered to all the classes. Three weeks later a test on logarithms to measure retention was administered to all the classes. Using Total SCAT scores, available from the Department of Education grade IX records, the students were subdivided into two categories. Two-way analysis of variance was carried out on the data to test the null hypotheses. Also, the students were subdivided into two categories on the basis of the SCAT Verbal scores, available from the Department of Education grade IX records, and a two-way analysis of variance was carried out on the data to test the null hypotheses.

On the basis of the analysis the following conclusions, within the limitations of this study, were made.

The programmed booklets provided a means of instruction which was as effective as the conventional method of teaching.

After a lapse of three weeks, students taught by programmed instruction, retained as much knowledge of logarithms as students taught by the conventional classroom method.

The experiment provided validation of the programmed booklets as a method of instruction for the material which they covered.

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TABLE OF CONTENTS

CHAPTER		PAGE
I	THE NATURE AND SIGNIFICANCE OF THE PROBLEM	1
	Introduction	1
	Background of the Problem	2
	The Problem	2
	The Experimental Setting	3
	Significance of the Problem	6
	Definition of Terms	7
	Outline of the Report	10
II	REVIEW OF THE LITERATURE	11
	The Nature of the Learning Process	12
	Utilization of Programmed Instruction in the Learning Process	14
	Programmed Instruction Techniques	18
	Related Studies and Research	20
	Research at the Elementary School Level	23
	Research at the Junior High School Level . . .	24
	Research at the Senior High School Level . . .	24
	Research at the College Level	25
	Research with different Programmed Instruction Methods	27
	Research with Different Methods of Responding	28
	Research with Different Intelligence Levels	29

CHAPTER		PAGE
	Research with Use of Programmed Materials . . .	30
	Conclusions	32
III	THE EXPERIMENTAL DESIGN AND THE STATISTICAL PROCEDURES	34
	The Nature of the Sample	34
	The Nature of the Materials	35
	The Testing Instruments	37
	Procedure	39
	Testing Program	39
	Teacher Procedure	40
	Treatment of the Data	41
	Null Hypotheses	42
	Summary	44
IV	THE RESULTS OF THE INVESTIGATION	45
	Comparison of Groups before Treatment	45
	Comparison of Groups after Treatment	51
	Procedure	51
	Summary of other Findings	56
	Teacher Characteristics	56
	Time Factor	60
	Student Questionnaire	60
	Chapter Summary	61

CHAPTER		PAGE
V	SUMMARY, CONCLUSIONS, LIMITATIONS AND IMPLICATIONS	63
	Summary of the Experiment	63
	Experimental Procedures	63
	Results of the Statistical Analyses	65
	Findings from the Student Questionnaire	65
	Conclusions	66
	Limitations	67
	Implications	68
BIBLIOGRAPHY		72
APPENDIX		78
	Scores for All Students	79
	Chi Square Test on Cell Frequencies	88

LIST OF TABLES

TABLE		PAGE
I	Cell Frequency for Instructional Groups and Scholastic Ability Level Classification	43
II	Cell Frequency for Instructional Groups and Verbal Ability Level Classification	43
III	Pre-Test Cell Means (Cells Based on Total SCAT Scores)	46
IV	Summary of Analysis of Variance of Pre-Test Scores (Ability Levels: Total SCAT Scores)	47
V	Pre-Test Cell Means (Cells Based on Verbal SCAT Scores)	49
VI	Summary of Analysis of Variance of Pre-Test Scores (Ability Levels: Verbal SCAT Scores)	50
VII	Post-Test Cell Means (Cells Based on Total SCAT Scores)	52
VIII	Post-Test Cell Means (Cells Based on Verbal SCAT Scores)	53
IX	Summary of Analysis of Variance of Post-Test Scores (Ability Levels: Total SCAT Scores)	54
X	Summary of Analysis of Variance of Post-Test Scores (Ability Levels: Verbal SCAT Scores)	55
XI	Retention Test Cell Means (Cells Based on Total SCAT Scores)	57

TABLE		PAGE
XII	Retention Test Cell Means (Cells Based on Verbal SCAT Scores)	58
XIII	Summary of Analysis of Variance of Retention Test Scores (Ability Levels: Total SCAT Scores) . . .	59
XIV	Summary of Analysis of Variance of Retention Test Scores (Ability Levels: Verbal SCAT Scores) . .	60
XV	Student Questionnaire Summary	62

CHAPTER I

THE NATURE AND SIGNIFICANCE OF THE PROBLEM

I. INTRODUCTION

The quickening pace of technological change and the tremendous population explosion are placing increasing demands on education. As Jenkinson asserts:

> Though change is perhaps "the blight man was born for" it must be acknowledged that change has been accelerated and gives no indication of early abatement. So many of our old problems are still with us. So many areas of knowledge are as yet incomplete. It has been long realized that provisions must be made for individual differences, but while many are undertaking experiments in this area the full implication of each adaption of method or administration has not always been realized.[1]

Coutts in a message addressed to the teachers of Alberta states:

> Knowledge -- both academic and professional -- continues to expand at an unprecedented rate. Hence professional groups are faced with the task of keeping informed about new concepts and improved procedures.[2]

These problems have created a climate in which the national spotlight is now focussed on education. Both business and government

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[1] Marion D. Jenkinson, "Some Implications of Psychological Research for Elementary Education" Canadian Education and Research Digest, C. Warrington (ed). (Toronto: Canadian Education Association, Vol. 2, Number 3, 1962), p. 195.

[2] Herbert T. Coutts, Dean, Faculty of Education, University of Alberta, Pamphlet Summer '67, Continuing Professional Education for Teachers (Faculty of Education, Department of Extension, University of Alberta.)

are watching to see how the educational establishment adapts existing patterns of instruction to the changing realities of the present and future.

Jack E. Forbes, Chairman of the Department of Mathematics, Purdue University and Director of Research at the Britannica Centre for Studies in Learning stated:

> In today's world of exploding knowledge it is necessary to capitalize on every method of communicating information and ideas.[3]

II. BACKGROUND OF THE PROBLEM

If education is to meet the challenge of increasing the efficiency and effectiveness of the instructional process, teachers must be given more opportunity to make optimum use of their teaching time. A primary objective of educational technology must be to develop instructional media which will help to maximize the effective use of teacher time. Experimentation and innovation in this area are widespread and the pace is accelerating. As a result, new types of instructional aids are being developed, one of which is programmed instruction.

III. THE PROBLEM

The purpose of this study was to compare experimentally the effectiveness of programmed instruction used during class time with

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[3]Stated in an address to teachers attending a seminar in programmed instruction in Edmonton during the summer of 1964.

that of the conventional method of teaching logarithms. Do students using programmed instructional materials only, develop as much understanding of the mathematical concepts as do students taught in the conventional manner?

How do students learning with programmed instructional materials only, compare with students taught in the traditional manner with respect to achievement as measured by a standardized mathematics test? Do students using programmed instructional materials only, retain as much knowledge of the mathematical concepts as do students taught in the conventional manner as measured by a conventional set of exercises, administered three weeks after completion of the unit study? This investigation was an attempt to gather objective evidence that might suggest answers to these questions.

IV. THE EXPERIMENTAL SETTING

The study was conducted during the spring of 1965 in the high schools of the Edmonton Separate School system. Five teachers participated in the study and each taught Mathematics 20 to two classes of students. These teachers did not indicate any pronounced bias for any particular method of teaching logarithms. They had similar backgrounds in teacher training, specialization and in teaching experience. All indicated a willingness to participate in this study.

A method of random selection was used to determine which of the two classes in each school would be taught in the conventional classroom manner and which would be taught by programmed instruction. Since the classes consisted mostly of girls, it was decided to use them as the experimental group. This provided a total of 175 subjects, 96 taught by the conventional classroom method and 79 taught by programmed instruction.

The unit on logarithms was selected for the study because for the first time (1964-65) it was included in the content of Mathematics 20.[4] The investigator was able to obtain permission from the Royal Canadian Air Force Instructional Wing, Clinton, Ontario, to use the programmed material[5] available on this unit. This material was prepared, tested and revised several times over a period of two years using approximately 1000 subjects.

The Cooperative Test: Intermediate Algebra (Quadratics and Beyond) Form Y was administered to all the classes during April, 1965. These results were used to determine the level of achievement of the students prior to initiation of the study. When the unit on logarithms was completed, Form Z of the Cooperative Test: Intermediate Algebra (Quadratics and Beyond) was administered for

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[4]Senior High School Mathematics Subcommittee, Senior High School Mathematics Bulletin, April 1964, p. 25.

[5]W. H. Farrel and others, Introductory Mathematics: Powers of Ten and Logarithms (Training Standards and Development Division, Royal Canadian Air Force, 1962).

the purpose of measuring growth and for making comparisons. Three weeks later a Retention Test was administered for the purpose of measuring retention of the content taught during the study.

Total and Verbal scores obtained from the School and College Ability Test (SCAT) administered at the time the students wrote the grade IX departmental examinations and as recorded by the Department of Education were used to separate the students into two categories.

Each teacher taught one class in the conventional manner and supervised the other during the regular mathematics periods. No assistance was given to the later class. The programmed material was collected at the end of each period and kept by the teacher until the next mathematics period at which time it was re-distributed to the students. Extra exercises were available to the students using the programmed material so that both classes completed the unit at approximately the same time. The teachers were urged to relate their teaching techniques as closely as possible with the suggested procedure in the text.[6] In this way it was hoped to reduce the differences in teaching approach of the individual teachers. Every attempt was made to keep other variables as constant as possible.

The findings of the experiment are based on the statistical analyses of the data gathered from the study.

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[6]Bowers, Miller and Rourke, Mathematics for Canadians, Book III (Toronto: J. M. Dent and Sons (Canada) Ltd., and the MacMillan Company of Canada Ltd., 1950).

V. SIGNIFICANCE OF THE PROBLEM

There is, of course, no doubt that the improvement of public education depends substantially on research. It is not difficult to imagine the reaction of teachers when, years ago, the first textbook was published. The teacher was not replaced by the textbook but the role of the teacher was changed. Freed from the need to present all of the content, the teacher had more time to explain the more enrichening points of the subject and to maintain student interest.

In recent years, one of the more important developments in the field of education has been the introduction of programmed instruction. Very briefly, it can be stated that programmed instruction is a system of teaching which exploits fully certain basic principles of learning. The learning principles are: the presentation of small, even minute, steps; active response by each student; immediate confirmation of progress; allowance for individual differences and immediate and constant reinforcement. Since its introduction programmed instruction has had its "ups" and "downs" but the new attitude toward the student --- that every student can learn --- can bear further investigation. This requires teachers to critically examine their own methods of instruction in light of the classroom situation.

In evaluating programmed instruction the critical area should be the prepared program and not the various refinements of

technique such as the "programmed text" or the "teaching machine". (Unfortunately, it is this latter aspect which has received the most publicity.)

An increasing number of programs are now becoming commercially available in a variety of subject matter areas. Mere availability is no guarantee of quality and visual inspection alone is not a sound criterion for judging the programs. In a study reported by Ernst Z. Rothkopf[7] a near perfect record of mistaken judgment was made by a group of high school principals and teachers who had just completed a three-week course in programmed instruction. Their selection of programs was plotted against the actual effectiveness as measured by a valid recall post-test.

It is only by gathering empirical evidence that the effectiveness of programmed instruction can be measured and it is only in this way that education can increase its efficiency in an era when efficiency is the vital element in keeping pace with the demands of the future.

VI. DEFINITION OF TERMS

In general, the meaning of each of the following terms and abbreviated forms of reference are indicated where first used, but, for easy reference the following list is presented:

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[7]Ernst Z. Rothkopf, Bell Telephone Laboratories Inc., Journal of Programmed Instruction (Summer 1963).

"Branching" is a particular type of program which has built-in alternate sequences. If a student makes a wrong response in a certain area, he is directed through alternate steps in the program designed to remedy his lack of understanding through additional explanations. Similarly, if a student demonstrates through a long series of correct responses that he has the required understanding of the subject matter, he may "skip" over additional information on the same topic.

"CON" refers to the group of students in the experiment who were taught by the conventional classroom method.

"COOP" refers to the <u>Cooperative</u> (Mathematics) <u>Tests</u>.

"Covert" response is a non-active response to a question such as thinking of an answer without writing anything down, pressing a button, etc.

"Eclectic programming" incorporates the more desirable features of both the extrinsic and intrinsic formats.

"Error rate" either refers to the number of errors a student makes in completing a program or to the percentage of the students giving wrong responses to a specific item on the program. It has value as a criterion in determining revisions to the program.

"Extrinsic programming" is a linear Skinnerian type of programming in which the program sequence is unalterable and is the same for all students.

"Frame" is a unit of the program which requires a response from the student. The information required to answer a given item

is contained in that item, in a preceding item or in both.

"Intrinsic programming" employs the branching technique where all possible sequences of item presentation are built into the program and controlled by the student responses rather than by any outside agency.

"Overt" response involves a physical activity on the part of the student such as writing, pressing a button, etc.

"Pacing" involves having the learner proceed at a rate at which almost all his responses are correct. In this way desired behavior is reinforced.

"PROG" refers to the group of students in the experiment who were taught by the method of programmed instruction.

"Program" consists of the subject matter arranged in units (frames) in such a way as to facilitate instruction.

"Prompts" are stimuli included in a program to increase the probability that a given response will occur.

"Reinforcement" is a basic concept of pyschology of utmost importance to programmed instruction theory. In order that a student retain a piece of information effectively, it must be reinforced by informing him that he is right.

"SCAT" refers to the <u>Cooperative School and College Ability Test</u>.

"Total SCAT score" refers to the sum of the scores of the subtests of the <u>SCAT test</u>.

"Verbal SCAT score" refers to the score of the verbal subtest of the <u>SCAT test</u>.

VII. OUTLINE OF THE REPORT

The present chapter is an introduction to and a preview of the study. Chapter II consists of an explanation of programmed instruction and a review of the literature that has a bearing on the study. Chapter III gives a detailed description of the design of the experiment and the statistical procedures used in analyzing the data. Chapter IV gives the results from the statistical analyses. Chapter V is devoted to a summary of the investigations along with the conclusions and implications for further research.

CHAPTER II

REVIEW OF THE LITERATURE

Programmed materials have had a relatively short but colorful history. This history has included charges and claims that have threatened to embroil this instructional tool so deeply in controversy that it would have little opportunity to make its impact on education. Yet, in a nation-wide survey of practices and innovations in American schools, Leonard[1] suggests that programmed instruction challenges all educators to critically examine and improve their method of instruction. In a report[2] published in the Reader's Digest the claim is made that learning power can be doubled with proper utilization of programmed instruction. Two senior officials of the Russian Bureau of Education[3] when asked to give their appraisal of Canadian facilities they visited on a

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[1] G. B. Leonard (senior ed), Testing vs. Your Child (New York Look, March 11, 1966), p. 64-68.

[2] W. Langewiesche, Now You Can Double Your Learning Power (Montreal: The Reader's Digest, April, 1967), p. 27-31.

[3] A. N. Osipov, Associate deputy minister for vocational education and A. I. Postukhov, senior inspector for technical education, U.S.S.R., in an interview with Southam Press, 1966.

cross-country tour said they were surprised they had seen no programmed instruction in use. In Russia, this method of instruction is used extensively at all levels of education.

Because much of the controversy is centered on how learning takes place, this aspect and its application to programmed instruction are now considered.

I. THE NATURE OF THE LEARNING PROCESS

A teacher's conception of learning and of the learner determines to a large extent his activity in the classroom. Tolman suggested that we should not limit ourselves to a single theory:

> I wish to suggest that our familiar theoretical disputes about learning may perhaps . . . be resolved if we can agree that there are really a number of different kinds of learning. For it may then turn out that the theory and laws appropriate to one kind may well be different from those appropriate to other kinds.[4]

Fehr explains human learning as:

> A change in behavior acquired through an experience. The learning is usually directed towards specific goals through patterns of experience.[5]

Further, it is emphasized that any formulation of learning that facilitates a technological approach to instruction must be

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[4]E. C. Tolman, "There is More than One Kind of Learning," Psychological Review, 56 (1949), p. 144.

[5]H. Fehr, "Theories of Learning Related to the Field of Mathematics," The Learning of Mathematics, Its Theory and Practice, (Washington, D.C.: The National Council of Teachers of Mathematics, 1953), XXI, p. 2.

one in which internal changes are considered to result in a new capability for some type of performance. According to Skinner[6] performance is the effect of learning on behavior and is the external sign that learning has occurred. Gagné[7] explains that the kind of change called "learning" exhibits itself as a change in performance, and the inference of learning is made by comparing what performance was possible before the individual was placed in a learning situation and what performance can be exhibited after such experience.

The process through which meaningful learning occurs is a subtle, intricate and complex phenomenon. According to Ausubel[8] this process involves the incorporation of a new learning task into existing cognitive structure so that a meaningful relationship is established. The new information must be mentally processed by the learner so that it becomes an integral part of his own particular system of knowledge. The learner must translate the new information into his own frame of reference. This interaction of a new learning task with existing cognitive structure is the distinctive feature of meaningful learning.

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[6]B. F. Skinner, "Reflections of a Decade of Teaching Machines," Programmed Learning and Teaching Machines II, Data and Directions (National Education Association, 1966), p. 5.

[7]R. M. Gagné, The Conditions of Learning (New York: Holt, Rinehart, and Winston, Inc., 1965).

[8]D. P. Ausubel, The Psychology of Meaningful Verbal Learning (New York and London: Gruen and Stratton, 1963).

Since the occurrence of meaningful learning is the result of the cognitive activity of the learner himself, the proponents of this theory of learning claim that learning does not have to occur in the physical presence of a teacher. However, for learning to take place most efficiently and effectively the learning process does need to be controlled. This process of exercising control is called teaching.

The control of the learning process is attained by structuring a learning situation so that each student experiences a series of learning activities by which he is continually guided toward achievement of the goals which have been set for him. The learner cannot be regarded as a passive agent but must be considered as an active participant in his own learning. It must be recognized that the efficiency with which the learning process is executed will vary with each learner, depending on his own cognitive structure and his ability to process information. Gains in learning will result directly from the effects of structuring the learning situation so that students are mentally engaged in learning activities and also to the extent that instructional guidance is provided on an individual basis.

II. UTILIZATION OF PROGRAMMED INSTRUCTION IN THE LEARNING PROCESS

> If by a miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page

> one would page two become visible, and so on, much that now requires personal instruction could be managed by print.[9]

Ayers, in a paper presented to the Third Canadian Conference on Educational Research cautioned against attempts to develop a single theory of instruction. Furthermore he stated:

> If we do not limit ourselves to one theory of learning or one theory of instruction, but select the most appropriate, then programmed instruction in its widest sense can serve as a useful tool.[10]

Programmed instruction is a new technological approach to the development of instructional materials. It condenses the necessary learning experiences as concisely and systematically as possible to insure that instructional objectives are achieved as efficiently as possible. The initial procedure in the programming process is to formulate the desired instructional objectives in such a manner as to allow the degree to which they are achieved by the learner to be empirically measured. An instructional objective is a statement which describes an intended outcome of instruction. To be measurable the objective must describe an intended outcome in operational terms, i.e., what activities will the learner be able to perform upon completion of instruction. After the objectives have been properly formulated and a valid measuring instrument

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[9] E. L. Thorndike, Education (New York: Macmillan Company, 1912).

[10] J. D. Ayers, "Programmed Instruction - Its Potential," Canadian Education and Research Digest 4 (September, 1964), pp. 219-220.

has been constructed, a level of performance is established as a criterion of acceptable performance.

The basic concept of the programmed approach is that all learners who possess the necessary knowledge prerequisites should achieve the established criterion of acceptable performance. If these learners fail to understand any part of the subject matter or fail to reach the criterion level, it is not the fault of the learners, but a signal that there is a weakness in the instructional process. These weaknesses must be located and revisions and adjustments made until they are eliminated.

The basic learning principle that facilitates this approach requires that the student be actively and continually involved in the learning experiences he encounters. The programmed approach utilizes this principle by breaking up subject matter into segments called "frames" and presenting only one frame at a time. The learner is asked to make an observable response (usually a written response) to each frame of the subject matter. Having to actually make an active response maintains his constant attention and also forces discriminative thinking about the material being presented.

Another important learning principle is that of immediately informing the learner as to the adequacy of his response. Immediate knowledge of correct responses lets a student know that he understands that part of the subject matter and is ready to proceed to the next. This maintains a high level of confidence, has a reinforcing effect and provides a strong motivating force. Immediate

knowledge of incorrect responses lets him know that he does not understand that part of the subject matter before he encounters the next, and that he needs to review or ask for additional explanation before proceeding. The programmed approach utilizes this principle by presenting the material in such a manner so that after the learner has responded, the correct response is available with which to compare his own before encountering the next frame of subject matter.

Another principle which is most critical to the learning process is that of allowing each individual student to proceed at his own pace. This allows each learner as much time as he needs to comprehend each part of the subject matter and make an adequate response. Since the programmed approach does not indicate a time limitation a student can actually learn at his own optimum rate.

The application of these principles not only increases the effectiveness with which subject matter is learned but also makes possible a systematic try-out and revision procedure. The purpose of this procedure would be to make revisions in the instruction until it fits the psychological state of the learner.

The final process to which programmed materials are subjected is a systematic validation procedure. It answers the question, "Does the program actually accomplish what it purports to accomplish?" Tests are made up of items which require the learner to perform the operation stated in the objectives.

Further, Crawford[11] states that because of the highly sequential nature of mathematics, programmed instruction seems to possess features favorable to teaching mathematics. He sums up his survey of teaching methods by saying that mathematics has to be learned rather than taught and that three general ways of ensuring this involves the use of discovery, games, and programmed instruction.

III. PROGRAMMED INSTRUCTION TECHNIQUES

Without going into a lengthy discourse into the various methods of programmed instruction, the details of which are available in many sources, notably, "Automated Teaching: The State of the Art"[12] and "Teaching Machines and Programmed Learning"[13], it is appropriate to mention briefly the two major "schools". B. F. Skinner of Harvard University developed a method which is based fundamentally on the behavioral psychology concept of learning. The material to be learned is presented in very small steps or frames which are carefully "programmed" in order to elicit the desired responses and guide the student to the required mastery of the subject matter.

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[11] D. H. Crawford, "Developments in School Mathematics in Canada - A Survey," Canadian Education and Research Digest 4 (December 1964), pp. 314-315.

[12] E. H. Galenter (ed), Automated Teaching: The State of the Art (New York: John Wiley and Sons, 1959), 198 pages.

[13] A. A. Lumsdaine and R. Glaser, Teaching Machines and Programmed Learning (National Education Association of the United States, October, 1960), 724 pages.

The "Skinnerian" method is described as "linear programming".

N. A. Crowder of the "Western Design Division" of "United States Industries" developed a method whereby material is presented in a variable sequence depending upon the progress of the individual student. A small amount of material is presented followed by a multiple-choice question. Dependent upon which answer the student selects, he is referred to one of three or more alternative pages. On the page he selects, the student is informed (if his answer is incorrect) of the nature of his error and/or provided with additional information and referred back to the original question. This method is described as "branching programming".

There has been much discussion regarding the pros and cons of the various methods of programming. There is, however, evidence in the literature that the divergent methods of programming are becoming somewhat closer in approach. Some programs seldom branch but do provide remedial or enrichment materials at appropriate points.[14] Some programs provide the better student with opportunities to "bridge" over certain material designed to give extra instruction for less able students.[15]

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[14] Modern Mathematics For the Junior High School (Encyclopaedia Britannica Press, Inc., Britannica House, Toronto). n.d.

[15] Modern Algebra - A First Course (Encyclopaedia Britannica Press, Inc., Britannica House, Toronto). n.d.

IV. RELATED STUDIES AND RESEARCH

Changes made in mathematics by modern research are equally as profound as those in chemistry, physics, and biology. The twentieth century may well become the golden age of mathematics, since more mathematics and more profound mathematics has been created in this period than during all the rest of history. If our schools are to reap the benefits of the progress made in mathematics certain requirements must be met: in-service retraining of teachers, better pre-service training and improved teaching techniques. The review of the literature will be concerned with programmed instruction as a technique of teaching.

Deterline summarized a number of findings of experiments involving the technique of programmed instruction. The first field study designed to test the effectiveness of auto-instruction was conducted by Klaus and Lumsdaine (1960, 1961). Some physics classes from Pittsburgh high schools were provided with a linear program dealing with electricity and light to be used as a supplement to their regular classroom instruction in this subject area. Some classes were provided with additional study workbooks while still other classes followed the ordinary classroom instruction. The performance of the students using the workbooks was compared with that of the students using the program:

> The results indicated that the classes using the program as a supplement did better on an achievement test than the students who had used neither the program nor the workbook.

> The workbook classes were superior to those having neither workbook nor program but were inferior in performance to the classes which had used the program.[16]

In another study done by the same research team, high school classes were used in a slightly different way; some were instructed by program alone, while others had the program plus teacher instruction. There was no significant difference in performance level.

Schramm summarized a great deal of research with programmed instruction which took place during the sixties. He estimated that 80 percent of this research dealt with testing and comparing various kinds or parts of the programs. He also found that:

> Among the remaining research experiments there are a considerable number of evaluative tests which seek to compare the amount of learning from programs with conventional classroom teaching of the same subject. A few experiments dealt with special applications of the program - to slow learners, deaf children, to industrial trainees and other groups.[17]

In answer to the question of whether students learn from programmed instruction, Schramm says:

> They do indeed learn . . . But the question, how well they learn from other kinds of instruction, we cannot answer confidently . . . let us record some of the evidence comparing programs with conventional classroom instruction. We have

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[16] W. A. Deterline, An Introduction to Programmed Instruction (Englewood Cliffs, N.J.: Prentice Hall, 1962), pp. 61-62.

[17] W. L. Schramm, "The Research of Programmed Instruction: An annotated Bibliography," United State Office of Education Bulletin No. 35 (Washington, D. C.: U. S. A. Department of Health, Education and Welfare, 1964), pp. 2-3.

> tabulated 36 such reports . . . Of the 36 comparisons, 18 showed no significant differences when the two groups were measured on the same criterion test. But 17 showed a significant superiority for the students who worked with the programs and only one showed a final superiority for the conventional classroom method.[18]

Strembisky, in an appraisal of research in programmed instruction recorded that the research was restricted to limited number of areas. His appraisal study[19] revealed that there was a tendency to favor programmed instruction in mathematics at the elementary level, but the majority of the findings were not rated as highly dependable. An even greater tendency was found to favor programmed instruction at the junior high school level, but again, the majority of the findings were not rated as being highly dependable. At the high school level there were no dependable findings but the general trend did indicate that programmed instruction and conventional techniques were equally effective in teaching mathematics. The appraisal revealed that programmed instruction in mathematics could be most successful in comparison to the conventional methods, at the college level. Most of the findings were rated as dependable and indicated that programmed instruction was at least as effective as the traditional methods of instruction.

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[18] W. Schramm, op. cit., pp. 3-4.

[19] J. Strembisky, "An Appraisal of Research in Programmed Instruction." Unpublished Master's thesis, The University of Alberta, 1964.

Research at the elementary school level. MacDonald conducted an experiment in teaching fractions to grade VI Indian, Eskimo, Metis, and white students residing in the Northwest Territories, using four different methods:

Method A - Programmed instruction only.

Method B - Programmed instruction and minimal teacher participation.

Method C - Programmed instruction and more teacher participation.

Method D - Conventional teaching only.

The four groups were matched in I.Q., ethnic origin and grade level. They were comparable in other factors. Analysis of the results revealed that:

1. Learning took place in each group.
2. Method C was the best of the programmed instruction methods.
3. There was no significant difference between method C and method D.
4. White pupils in group C did better on the post-test than white pupils in all other groups.
5. Native pupils showed no significant difference between method C and method D.[20]

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[20] H. A. MacDonald, "Programmed Instruction with Teacher Participation: An Experiment in Teaching Fractions to Children Who Reside in the Northwest Territories." Unpublished Master's Thesis, The University of McGill, Montreal, 1966.

Research at the junior high school level. Randolph conducted an experiment in modern mathematics (sets, relations, and functions) with programmed instruction. The experiment extended over a period of nine weeks. The conclusions recorded were:

1. That there was a real gain in achievement. This confirmed a study by McGarvey[21] who had reported outstanding results.

2. That students tended to become tired of programmed instruction, which confirmed a conclusion arrived at by Henderson.[22] However, whereas Henderson reported that programmed instruction was valuable for the slower student, Randolph indicated that it was more suitable for the brighter student. (There is a possibility that programmed instruction is a valuable aid for both extremes of students, with different materials for each extremity.)

3. That gifted students in junior high schools can learn advanced material by programmed learning and can benefit from such a program.[23]

Research at the senior high school level. Jordy carried out a comparative study of methods of teaching plane geometry in high

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[21] P. McGarvey, "Programmed Instruction in Ninth-Grade Algebra," The Mathematics Teacher, LV (November, 1962), pp. 576-578.

[22] G. L. Henderson, "An Independent Classroom Experiment Using Teaching Machine Programmed Materials," The Mathematics Teacher, LVI (April, 1963), pp. 248-251.

[23] P. H. Randolph, "An Experiment in Programmed Instruction in Junior High School," The Mathematics Teacher, LVII (March, 1964), pp. 160-162.

school. One group of grade XI students used programmed materials and another group was instructed by the conventional lecture-recitation method. A reading test was administered as well with the purpose of investigating the effect on the reading level between the two groups. The outcomes reported by the author were:

1. Ability directly affects the achievement in plane geometry. When a student has the opportunity to learn at his own rate of comprehension, learning is increased and understanding is improved.

2. The boredom arising from the use of programmed materials can be reduced by using materials written on an individual unit basis and also to allow some class time for discussion.

3. Programmed learning did improve the overall reading ability. Reading for comprehension was reinforced.

4. Where the maturity of the students involved is great enough that they accept the rigors of self-discipline necessary for successful completion of programmed materials and have above average ability, programmed materials have a definite value.[24]

Research at the college level. This experiment conducted by Dobyns could be classified as a related project. Dobyns used six classes of thirty students from the Louisiana State College.

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[24] J. L. Jordy, "A Comparative Study of Methods of Teaching Plane Geometry." The Mathematics Teacher LVII (November, 1964), pp. 472-478.

Three teachers participated in the study and taught two classes each. One class was given programmed materials and the other class was taught by the conventional method. The subject matter consisted of sets, numbers and algebra of numbers as a logical system. Each class met nine times. During the next ten classes both groups were taught by the conventional method the topic of logic. During the third phase the three classes that did not use programmed materials previously were given such materials dealing with inequalities, absolute values, coordinate systems, functions and their graphical representation. The other classes were taught in the conventional manner. Tests were administered at the end of each phase to all the classes.

On the basis of the analysis the following conclusions were made:

1. The programmed booklets covering sets, numbers, and the algebra of numbers as a logical system provided a means of instruction which was as effective as the conventional method.

2. The programmed booklets covering inequalities, absolute values, coordinate systems and their graphical representation provided a means of instruction which was more effective than the conventional method of teaching.

3. After being taught by programmed instruction, the students still learned effectively by the conventional method of instruction.

4. The experiment provided validation of the programmed booklets as a method of instruction for the materials which they cover.[25]

Research with different programmed instruction methods. Branching and linear presentation of programmed materials tend to be equally effective. In a study reported by the Royal Canadian Air Force programmed instruction was used as a teaching medium of basic mathematics required by trainees in the Radar and Communications School. One group of 400 trainees used a branching program and another group used a linear program. The two programs were developed and equated for difficulty through experimentation with random groups of trainees available the previous year. The trainees spent ninety minutes per day on the programs for approximately two weeks. No talking or discussion was permitted during the sessions and trainees were not permitted to take the programmed material out of the classroom. Although this study did not evaluate the relative merits of the two programs, other conclusions became apparent:

1. Both groups showed a significant increase in achievement. The group using the branching program showed an increase of 21.3 percent and the group using the linear program an increase of 17.0 percent.

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[25] R. A. Dobyns, "An Experiment in the Teaching of College Algebra," The Mathematics Teacher, LVII (February, 1964), pp. 86-88.

2. Effective learning can be attained through the use of programmed materials alone.

3. Students of widely varying educational backgrounds (Grade 7 to first year university) can learn from the same program at the same time.[26]

Research with different methods of responding. Unruh conducted an investigation in this area. With a program on grammar, students who responded covertly (A) and overtly (B) to materials presented by machine learned significantly more than students who read the program, filled in blanks and underlined (C), or students who studied textual material and did a daily quiz (D). Group (B) took fifty percent more time to complete the program. There was no significant difference in the amount learned by the high or low I.Q. groups.[27]

Krumboltz, using undergraduate and graduate college students, compared key-word response in programmed instruction with the reading of the same material in paragraph form with no required response. He found no significant differences on the post-test.[28]

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[26] Training Standards and Development Division of the Radar and Communications School, "An Evaluation of Programmed Instruction in Elementary Mathematics," (published report) 1963.

[27] W. R. Unruh, "An Investigation of Four Methods of Presending Programmed Material," Unpublished Master's Thesis, The University of Alberta, 1962.

[28] J. D. Krumboltz, "The Nature and Importance of the Required Response in Programmed Instruction," Report to American Educational Research Association (Chicago, February, 1963) mimeographed.

In a similar experiment at the college level Evans compared a programmed text with a conventional text. Three topics -- number bases, statistics, and music -- were used. The post-test scores were higher for those using the programmed text but only were significant for the topic in music.[29]

Research with different intelligence levels. There are conflicting results in determining the relationship of intelligence to success in programmed instruction.

Feldhusen found that I.Q. was not a fundamental learning variable and that the variance in learning attributed to I.Q. seemed less important than that attributed to general achievement level.[30]

On the other hand, Lambert, using a program on modern mathematics for ninth graders, reported that intelligence was significantly associated with the amount of information acquired from the program.[31]

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[29] J. L. Evans, R. Glaser, and L. E. Homme, "An Investigation of Variation in the Properties of Verbal Learning Sequence of the 'Teaching Machine Type'," Teaching Machines and Programmed Learning: A Source Book (Washington, D.C.: Department of Audio-Visual Instruction, National Education Society, 1960), pp. 446-461.

[30] J. F. Feldhusen and A. Birt, "A Study of Nine Methods of Programmed Learning Materials," Journal of Educational Research, 55 (1962), pp. 461-466.

[31] P. Lambert, D. M. Miller, and D. E. Wiley, "Experimental Folklore and Experimentation: The Study of Programmed Learning in the Wauwatosa Public Schools," Journal of Educational Research, 515 (1962), pp. 485-494.

Research with use of programmed materials. There is evidence that programmed material is being used in the classroom for enrichment nearly as much as for any other single purpose.[32] However, Bale states that:

> Although programmed instruction is popular its superiority is unproved. A basic program of enrichment with materials or activities varied to suit the different types of potentially talented mathematics students is needed. An experimental study of various materials or activities such as programmed text versus conventional text may indicate the kind of enrichment differentiation needed.[33]

Garrison studied the effectiveness of programmed material as a supplement of elementary algebra over several ability levels. One group studied programmed materials using a teaching machine during class time for 15 minutes each day at their own rate. A second group did the same, but did so after regular school hours. The third group, the control group, continued in their usual fashion in the regular class. Each group contained high, average, and low intelligence levels of students. The high ability students used the machines more than the other two levels of students. The group which used regular class time for the program achieved better results, but the

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[32] A Survey of the Use of Programmed Instruction in Canadian Schools, 1962-63 (Research Memo No. 12, Ottawa Research Division, Canadian Teachers' Federation, September, 1963).

[33] D. J. Bale, "A Comparison of Programmed and Conventional Mathematics Enrichment Materials over Two Grade Seven Mathematics Achievement Levels," Unpublished Master's Thesis, The University of Alberta, 1966.

difference was not significant at the 0.05 level of confidence.[34]

Lane investigated the use of programmed instruction as a supplement to teaching college mathematics by closed-circuit television. Students enrolled in "Fundamental Principels of Mathematics" at the Nashville College for Teachers were assigned at random to one of three treatment groups. Each group watched the same televised lecture. Group I viewed a kinescope film of the solutions of the homework exercises. Group II participated in a classroom help session. Group III studies a programmed booklet based on the assigned exercises. After twelve class meetings, the students were given an achievement test. On the basis of the analysis the following conclusions were drawn:

1. The programmed material provided a supplement to televised instruction which was more effective than either of the other two supplementary methods.

2. The classroom discussion and the kinescope film session appeared to be equally effective.

3. The experiment showed validation of the programmed booklet as a method of instruction for the material which it covers.[35]

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[34]N. Garrison, "Effectiveness of Programmed Material As A Supplement for Elementary Algebra over Several Ability Levels."

[35]B. R. Lane, "An Experiment with Programmed Instruction as a Supplement to Teaching College Mathematics by Closed Circuit Television," The Mathematics Teacher, LVII (October, 1964), pp. 395-397.

V. CONCLUSIONS

There can be no doubt that the programmed instruction movement has provided the impetus for reconsidering, as well as the ideas for implementing, a number of time-honored principles of learning. Renewed interest in effecting more well-directed student participation in the learning process is a case in point.

Essentially, programmed instruction is a self-teaching device. The device itself may be a teaching machine, a programmed text, or a notebook with the following principles in common:

1. Material is presented in small sequential steps which require the student to respond.

2. The student must make a response . . . be it writing or pressing a mechanical device signifying an answer.

3. The response must be reinforced. It is a self-scoring device and may, as in branching programs, even tell the student why he is wrong and show him how the correct answer can be found.

4. It is self-pacing in that students determine the speed of presentation.

Construction of programs requires the observance of two basic requirements:

1. Before preparing a program it is necessary to formulate, as precisely as possible, statements of the desired objectives of the program.

2. The program is not complete until the writer is assured . . . through testing . . . that the program does, in fact, teach what it is supposed to teach.

Generalizing over a wide range of subject matter, the evidence indicates that anything that can be tested can be programmed and conversely anything that can be programmed can be tested. The evidence also indicates that students can be taught as efficiently by programmed instruction as they can by the conventional classroom presentation. These studies, as a group, are not characterized by sophisticated experimental design nor by scrupulous control of extraneous variables. However, the majority of them did employ some form of statistical test to test the significance of differences among groups on criterion test scores.

A large and promising area of exploration grows out of the exploding interest in recent years in the use of films, television, and other such media for the purpose of instruction.

CHAPTER III

THE EXPERIMENTAL DESIGN AND THE STATISTICAL PROCEDURES

The purpose of this study was to compare experimentally the effectiveness of a programmed text used during class time with the conventional method of teaching logarithms to Mathematics 20 students.

This chapter contains a detailed description of the sample and the materials used in the experiment, the achievement tests, the design of the experiment and the procedures followed in processing the data.

I. THE NATURE OF THE SAMPLE

The study was conducted during the spring, 1965. Permission was granted by the administration of the Edmonton Separate Schools to use pupils of their system. Those teachers who taught two classes of Mathematics 20 were asked to co-operate. This provided ten classes . . . two from each of five high schools . . . and five teachers. Since most of the students were girls, the data required for the study was limited to them. Total and Verbal scores were obtained from Department of Education records as established by a SCAT test written by the students at the time they wrote the grade IX departmental examinations (1963). With

these conditions set, the experimental population amounted to 175 students. The sample was divided into two treatment groups by random assignment and each group in turn was subdivided into two categories. This subdivision was determined in two different ways:

a) on the basis of Total SCAT scores, and

b) on the basis of Verbal SCAT scores only.

The unit on logarithms was selected for the study because for the first time it was included as part of the course outline for Mathematics 20.[1]

II. THE NATURE OF THE MATERIALS

Programmed materials are different from ordinary instructional materials in that they are specifically designed to enable students to learn specific areas of course content in a self-instructional manner through interaction with the materials. Consequently, these materials accept considerably more responsibility for bringing about learning than ordinary textbooks, which traditionally have performed the function of supplying the teacher with material from which to teach rather than supplying the learner with materials from which to learn.

In the review of the literature it is stressed that mere availability of a program is no guarantee of quality. The

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[1]Alberta Senior High School Mathematics Subcommittee, Senior High School Curriculum Guide for Mathematics 10 and Mathematics 20, September, 1963, p. 25. (pamphlet)

effectiveness of programs as teaching instruments will vary from highly effective to extremely poor, depending on the thoroughness of each particular program's development.

The initial step in the process of program development is to establish specific objectives for the program. These are stated in terms of what the student should be able to do when he completes the program. Next, the program criterion must be established. This asks: how well must the learner be able to perform? Then a valid achievement test must be constructed to serve as an instrument in measuring the actual level of performance.

In the next step, the entire field of subject matter is carefully analyzed to determine what is necessary for the students to learn in order to acquire the pre-determined behaviors. Once this body of subject matter is identified, it is ordered in a logical, well-sequenced progression in order to lead the student to the desired behaviors. These are tried and tested on individuals or small groups, representative of the target population. This try-out is designed to eliminate the major weaknesses in the program. During the field testing, elimination of weaknesses and revisions continue until all obvious patterns of weakness are eliminated or until the pre-determined level of effectiveness is reached.

This procedure of development was followed in the construction of the programmed text materials used in this study. During

1962 approximately one thousand individuals were involved in the testing and revisions that were required in this regard. The co-operation of the Training Standards and Development Division of the Radar and Communication School of the Royal Canadian Air Force in providing the programmed text materials is gratefully acknowledged. The material was compiled in 250 frames utilizing the linear (extrinsic) method of presentation. Frame (1) was presented on page one; frame (2) and the answer to frame (1) were presented on the next page and so on. Eventually students were directed back to page one for the next frame and the answer to the previous frame. This pattern was continued until all the pages were filled.

In addition, drill exercises were provided, to be done at the conclusion of specified frames to reinforce concepts presented in that series of frames. Other drill exercises were available for those students who completed the program ahead of their classmates.

The investigator felt that the programmed text material was a fair representation of the materials on this unit in the authorized text.[2]

III. THE TESTING INSTRUMENTS

The scores used in this study were determined from:

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[2]Bowers, Miller, and Rourke, Mathematics for Canadians, Book 3 (J. M. Dent and Sons and the Macmillan Company of Canada, 1950), Chapter XIII, pp. 292-319.

a) School and College Ability Tests (SCAT).

b) The Cooperative High School Mathematics Tests. Intermediate Algebra (Quadratics and Beyond), Forms Y and Z.

c) Logarithm Retention Test.

The purpose of the Cooperative School and College Ability Tests (SCAT) is to evaluate the students' capacity to perform academic tasks at the next higher school level. SCAT measures developed ability in Verbal and Quantitative skills and also yields a Total score. Individual performance is interpreted by means of converted scores and percentile bands. This test was made available by the Department of Education and was administered to the students at the time they were writing the departmental examinations in grade IX. If the Total and Verbal scores were available those students were included in the study. These scores determined the high (HI) and low (LO) categories in the two treatment groups.

The Cooperative Test Division[3] has followed the developments in mathematics and has taken the major trends into consideration in planning tests and revising existing instruments. Some of the newer emphases in language and content can be found in these tests, but in the main important aspects of traditional mathematics continue to be measured. Intermediate Algebra (Quadratics and Beyond) consists of a combination of discrete items and sets which require a knowledge of terms and concepts as well as problem solving.

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[3]Educational Testing Service, Cooperative Intermediate Algebra Test (Quadratics and Beyond). (Princeton: Cooperative Test Division, Educational Testing Service).

Forms Y and Z were used as the pre-test and post-test respectively. Scores on the forms are comparable because of the system of Scaled Scores which was developed for the Cooperative tests. The raw scores are converted to Scaled Scores by means of published tables.

There was no documented evidence as to the validity and reliability of the logarithm Retention Test which was used to determine the retention of the subject matter presented to both groups. The test was available in the school library. In the opinion of the teachers concerned and other teachers who used the test, it served as a fair measure of achievement.

IV. PROCEDURE

Testing Program. The Cooperative High School Mathematics Test: Intermediate Algebra (Quadratics and Beyond) Form Y, was administered as a pre-test to all the students in the experimental classes. Each teacher administered the tests to his or her own classes according to the uniform instructions provided. All the test papers were collected immediately and scored by the investigator.

Two weeks later the same test, Form Z was administered as a post-test to all the students in the experimental classes immediately following the instruction of the unit. Each teacher gave the

the post-test under conditions as similar as possible to those under which the pre-test was administered. Again, the test papers were collected immediately and scored by the investigator.

Three weeks after the post-test was administered the Logarithm Retention Test was given by the teachers according to the uniform instructions provided. Once again, the test papers were marked by the investigator.

Teacher Procedure. One of the classes belonging to each teacher was randomly designated as a control group (CON) class and the other class became a programmed instruction group (PROG) class.

The PROG group was issued the programmed instruction materials and was briefed by their teacher regarding the use of these materials. They were instructed to use the materials during the regular class periods only and to turn in the materials at the end of each period. They were urged to read and follow the instructions carefully because the teacher would only be involved in a supervisory capacity.

In teaching the CON group, the teachers were asked to use a method of presentation which would conform closely with the suggested procedures in the authorized textbook.

Since the study was conducted in a practical school situation it was not possible to have made a random assignment of pupils, teachers and treatments. However, every attempt was made to keep other variables as nearly constant as possible. Data on the

characteristics of the teachers involved in the study were collected. This information is presented in the next chapter.

At the conclusion of the study the PROG group was asked to complete a questionnaire which was prepared by the investigator. The summary of this questionnaire is also presented in the next chapter.

V. TREATMENT OF THE DATA

A binary-coded punched data card, containing I.D. numbers and test scores, was prepared for each student. Permission was granted by the University of Alberta Computing Centre to use their facilities to process the data in order to make statistical tests.

Since rigorous experimental controls on the characteristics of the group could not be employed, the first consideration was to test for significant differences between the groups. The groups were each divided in two ways, first, into scholastic ability levels in order that the effects of the different treatments on students of different scholastic abilities could be assessed, and secondly, into two verbal ability levels, in order that the effects of the different treatments on students of different verbal abilities could be assessed.

The frequency distribution for each basis was established and then arbitrarily, the groups were divided into two categories. To illustrate: on the basis of the Total SCAT scores, a student with a score of 71 or above was classified as scoring in the upper

half of the scholastic ability range (HI), and one whose score was 70 or less was classified as scoring in the lower half of the scholastic ability range (LO). Thus each student was classified by treatment as CON or PROG and by scholastic ability as HI or LO. The number of students classified in each cell is indicated in Table I.

Another division of the groups was made on the basis of Verbal SCAT scores, using a score of stanine 7 and above for the upper level (HI), and a score of stanine 6 or less for the lower level (LO). Each student was again classified by treatment as CON or PROG and by verbal ability as HI or LO. The number of students classified in each cell is indicated in Table II.

A chi square test[4] carried out on the cell frequencies in Table I and II showed that they were not significantly different from being proportional to the row and column totals.

Since it was observed[5] that there was no significant difference between the means of pre-test scores obtained by the CON and PROG groups it was considered appropriate to utilize the computational procedures for a two-way unweighted means analysis of variance[6] to test the following null hypotheses:

1. There is no significant difference between the mean post-test Cooperative Intermediate Algebra Scores obtained by:

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[4] Details given in the Appendix.

[5] Chapter IV of this study.

[6] B. J. Winer, Statistical Principles in Experimental Design (New York: McGraw-Hill Book Company, 1962), p. 93.

TABLE I

CELL FREQUENCIES FOR INSTRUCTIONAL GROUPS AND SCHOLASTIC ABILITY LEVEL CLASSIFICATION

GROUP	VERBAL SCAT SCORE HI	LO	TOTAL
CON	40	56	96
PROG	47	32	79
TOTAL	87	88	175

TABLE II

CELL FREQUENCIES FOR INSTRUCTIONAL GROUPS AND VERBAL ABILITY LEVEL CLASSIFICATION

GROUP	VERBAL SCAT SCORE HI	LO	TOTAL
CON	34	62	96
PROG	34	45	79
TOTAL	68	107	175

a) the CON and PROG groups,

b) the HI and LO scholastic ability (total; verbal) groups.

2. There is no significant difference between the mean Logarithm Retention Scores obtained by:

a) the CON and PROG groups,

b) the HI and LO scholastic ability (total; verbal) groups.

Whenever statistical tests on the differences between means were carried out, 0.01 level critical value was used. Consequently, the conclusions reached in this report on the basis of statistical tests are relatively conservative since the probability of indicating a significant difference between means as a result of sampling error is only 0.01.

Summary. The present chapter has been a description of the nature of the components of the experiment, of the experimental design and the statistical procedures followed in analyzing the data. The next chapter presents the results of the analysis of the data.

CHAPTER IV

THE RESULTS OF THE INVESTIGATION

I. COMPARISON OF GROUPS BEFORE TREATMENT

The first consideration was to test for significant differences between the two treatment groups with respect to initial achievement mean scores. An analysis was carried out to test that:

There is no significant difference between the mean pre-test _Co-operative Intermediate Algebra_ scores obtained by:

a) the CON and PROG groups,

b) the HI and LO scholastic ability (total) groups.

Table III lists the pre-test cell means and the results of the analysis are summarized in Table IV.

Inspection of the F-ratios in Table IV shows that there is no significant difference between the mean scores obtained by the two treatment groups. The observed F-ratio (0.055) did not exceed the critical value (6.71).

Further, the observed F-ratio (0.11) attributed to interaction did not exceed the critical value (6.71) so the interaction effect was not statistically significant.

The students in the HI scholastic ability level scored higher than the students in the LO scholastic ability level. The observed F-ratio (31.65) exceeded the critical value (6.71). This was a reasonable result to expect.

TABLE III

PRE-TEST CELL MEANS

CELLS DETERMINED BY TOTAL SCAT
(PERCENTILE SCORES)

	HI	LO	GROUP MEAN
CON	57.32	53.11	54.86
PROG	57.79	53.03	55.86
		Grand Mean	55.31

Pre-test: Intermediate Algebra (Quadratics and Beyond) Form Y.

TABLE IV

SUMMARY OF ANALYSIS OF VARIANCE

OF PRE-TEST SCORES

SOURCE	SS	DF	MS	F
A (Ability)	844.29	1	844.29	31.65
B (Group)	1.47	1	1.47	0.055
AB (Interaction)	2.95	1	2.95	0.11
Within	4561.1	171	26.67	

Ability Levels: TOTAL SCAT SCORES

Pre-test: Intermediate Algebra (Quadratics and Beyond) Form Y.

$$F_{.01}(1,171) = 6.71$$

An analysis was also carried out to test that:

There is no significant difference between the mean pre-test Co-operative Intermediate Algebra scores obtained by:

a) the CON and PROG groups,

b) the HI and LO scholastic ability (verbal) groups.

Table V lists the pre-test cell means and the results of the analyses of variance are summarized in Table VI.

Inspection of the F-ratios in Table VI shows that there is no significant difference between the mean scores obtained by the two treatment groups. The observed F-ratio (0.76) did not exceed the critical value (6.71)

The effect of interaction was not statistically significant because the observed F-ratio (-0.01) did not exceed the critical value (6.71).

Again, the students in the HI verbal ability level scored higher than the students in the LO verbal ability level. The observed F-ratio (17.78) exceeded the critical value (6.71). However, this was a reasonable result to expect.

The computational procedure for the unweighted means analysis of variance as described by Winer[1] and programmed for use with the University of Alberta's computer, was made available to the

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[1] B. j. Winer, Statistical Principles in Experimental Design (Edition II) (New York: McGraw-Hill Book Company, Inc., 1962), pp. 241-244.

TABLE V

PRE-TEST CELL MEANS

CELLS DETERMINED BY VERBAL SCAT SCORES

	HI	LO	GROUP MEAN
CON	57.15	53.61	54.86
PROG	57.85	54.36	55.86
		Grand Mean	55.32

Pre-Test: Intermediate Algebra (Quadratics and Beyond) Form Y.

TABLE VI

SUMMARY OF ANALYSIS OF VARIANCE

OF PRE-TEST SCORES

SOURCE	SS	DF	MS	F
A (Ability)	508.91	1	508.91	17.78
B (Group)	21.71	1	21.71	0.76
AB (Interaction)	-0.32	1	-0.32	-0.01
Within	4895.69	171	28.63	

Ability Levels: VERBAL SCAT SCORES

Pre-test: Intermediate Algebra (Quadratics and Beyond) Form Y.

$$F_{.01}(1,171) = 6.71$$

investigator to carry out tests of null hypotheses.

II. COMPARISON OF GROUPS AFTER TREATMENT

Procedure. Each of the null hypotheses tested is stated immediately before the presentation of the results of the appropriate statistical tests.

Null Hypothesis 1. There is no significant difference between the mean post-test Co-operative Intermediate Algebra scores obtained by:
a) the CON and PROG groups,
b) the HI and LO scholastic ability (total; verbal) groups.

Tables VII and VIII list the post-test cell means and Tables IX and X summarize the analysis of variance carried out on the post-test scores.

Conclusions. Examination of Tables IX and X and the critical F-ratio led to the following decisions:

Null Hypothesis 1-a was accepted.

Null Hypothesis 1-b was rejected.

Interpretations. There was no significant difference between the two treatment groups post-test mean scores. The interaction effect in all cases was not statistically significant.

The students in the higher ability range (HI) scored significantly higher than the students in the lower ability level (LO).

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[2] See page 42.

TABLE VII

POST-TEST CELL MEANS

CELLS DETERMINED BY TOTAL SCAT
(PERCENTILE SCORES)

	HI	LO	GROUP MEANS
CON	59.17	54.50	56.44
PROG	59.23	54.59	57.35
		Grand Mean	56.86

Post-test: Intermediate Algebra (Quadratics and Beyond) Form Z.

TABLE VIII

POST-TEST CELL MEANS

CELLS DETERMINED BY VERBAL SCAT SCORES

	HI	LO	GROUP MEAN
CON	58.59	55.27	56.45
PROG	59.32	55.87	57.35
		Grand Mean	56.86

Post-test: Intermediate Algebra (Quadratics and Beyond) Form Z.

TABLE IX

SUMMARY OF ANALYSIS OF VARIANCE

OF POST-TEST SCORES

SOURCE	SS	DF	MS	F
A (Ability)	909.81	1	909.81	48.08
B (Group)	0.164	1	0.164	0.01
AB (Interaction)	0.00	1	0.00	0.00
Within	3236.00	171	18.92	

Ability Levels: TOTAL SCAT SCORES

Post-test: Intermediate Algebra (Quadratics and Beyond) Form Z.

$$F_{.01}(1,171) = 6.71$$

TABLE X

SUMMARY OF ANALYSIS OF VARIANCE

OF POST-TEST SCORES

SOURCE	SS	DF	MS	F
A (Ability)	471.77	1	471.77	21.90
B (Group)	18.17	1	18.17	0.84
AB (Interaction)	0.16	1	0.16	0.01
Within	3683.38	171	21.54	

Ability Levels: VERBAL SCAT SCORES

Post-test: _Intermediate_ _Algebra_ (Quadratics and Beydnd) _Form_ _Z_.

$$F_{.01}\ (1,171) = 6.71$$

Null Hypothesis 2. There is no significant difference between the mean Logarithm Retention Scores obtained by:

a) the CON and PROG groups,
b) the Hi and LO scholastic ability (total; verbal) groups.

Tables XI and XII list the post-test cell means and Tables XIII and XIV summarize the analysis of variance carried out on the retention scores.

Conclusions. Examination of Tables XII and XIV and the critical F-ratio led to the following decisions:

Null Hypothesis 2-a was accepted.

Null Hypothesis 2-b was rejected.

Interpretations. There was no significant difference between the two treatment groups' mean retention scores. The interaction effect in all cases was not statistically significant.

As was expected, the students in the higher ability range (HI) scored significantly higher than the students in the lower ability level (LO).

III. SUMMARY OF OTHER FINDINGS

Teacher Characteristics. Although it is difficult to rate a teacher's effectiveness on the basis of university course background and on the number of years of teaching experience, this information was sought when the teachers were interviewed. There were only five teachers involved in the experiment because each

TABLE XI

RETENTION-TEST CELL MEANS

CELLS DETERMINED BY TOTAL SCAT
(PERCENTILE) SCORES

	HI	LO	GROUP MEAN
CON	4.90	4.14	4.46
PROG	5.47	3.13	4.52
		Grand Mean	4.49

TABLE XII

RETENTION-TEST CELL MEANS

CELLS DETERMINED BY VERBAL SCAT SCORES

	HI	LO	GROUP MEAN
CON	5.09	4.11	4.46
PROG	5.62	3.69	4.52
		Grand Mean	4.49

TABLE XIII

SUMMARY OF ANALYSIS OF VARIANCE

OF RETENTION-TEST

SOURCE	SS	DF	MS	F
A (Ability)	100.77	1	100.77	17.37
B (Group)	2.12	1	2.12	0.37
AB (Interaction)	26.37	1	26.37	4.55
Within	991.66	171	5.80	

Ability Levels: TOTAL SCAT SCORES

$F_{.01}$ (1,171) = 6.71

TABLE XIV

SUMMARY OF ANALYSIS OF VARIANCE

OF RETENTION-TEST

SOURCE	SS	DF	MS	F
A (Ability)	86.79	1	86.79	14.60
B (Group)	0.12	1	0.12	0.20
AB (Interaction)	9.35	1	9.35	1.57
Within	1016.62	171	5.95	

Ability Levels: VERBAL SCAT SCORES

$F_{.01}$ (1,171) = 6.71

was associated with one control and one experimental class. The information gathered in the interviews indicated that the teacher training varied from four to five years of university education and teaching experience ranged from 3 to 6 years. No teacher had any special training or experience in the teaching of logarithms.

Time Factor. The length of time required for the experimental group (PROG) to complete the program coincided closely with the time required to teach the unit in the traditional classroom method to the control group (CON). The time required for the completion of the experiment was two weeks and three additional class periods to write the tests. Further, the experimental group was provided with additional drill-type problems in lieu of assignments and to also control the time factor within the group.

Student Questionnaire. The students in the PROG group were asked to complete a questionnaire and to make comments concerning programmed instruction. They were encouraged to give their views on features of programmed instruction they liked and disliked. A summary of these remarks follows:

1. The majority expressed approval of the facility to work at their own speed and particularly when proceeding through difficult material.

2. Many students would prefer a mixture of programmed instruction and conventional teaching.

3. Many stated they would like to use programmed material and at the same time be able to ask questions and discuss difficult points with the teacher.

4. The students were divided on the point of whether more review should be included in the booklet.

5. The feature most students disliked was the boredom of "turning pages" all the time. This was considered a waste of time.

A summary of the questionnaire is presented in Table XV.

IV. CHAPTER SUMMARY

In all cases in the treatment of the data from the experiment, the differences between two means was considered to be statistically significant only if the probability of observing such a difference as a result of sampling error was 0.01 or less.

For all comparisons made between HI and LO ability levels, the results from a two-way analysis of variance revealed significant differences at the 0.01 level on the post-test and the retention test. This evidence was expected. The conclusions were the same whether the two levels were established on the basis of the Total SCAT scores or the Verbal SCAT scores.

There was no evidence to indicate that interaction was statistically significant with any of the statistical models used.

In all cases a comparison of the means between the two treatment groups by a two-way analysis of variance indicated no significant differences at the 0.01 level of confidence.

TABLE XV

STUDENT QUESTIONNAIRE

1. WOULD YOU LIKE TO STUDY ANOTHER UNIT USING THIS METHOD OF INSTRUCTION?
   YES 56%
   NO 44%

2. DID YOU FIND THE INSTRUCTIONS EASY TO FOLLOW?
   YES 81%
   NO 19%

3. DO YOU THINK THIS TYPE OF LEARNING IS (check one)
   - EASIER THAN LEARNING IN CLASS FROM A TEACHER 32%
   - ABOUT AS EASY AS LEARNING FROM A TEACHER 38%
   - MORE DIFFICULT THAN LEARNING FROM A TEACHER 30%

4. DO YOU THINK LEARNING IS (check one)
   - QUICKER THAN LEARNING IN CLASS FROM A TEACHER 20%
   - ABOUT AS QUICK 44%
   - SLOWER THAN LEARNING IN CLASS FROM A TEACHER 36%

5. (Check only one for each statement)

	CONSIDERABLE ADVANTAGE	SLIGHT ADVANT.	NO ADVANT.
AN INDIVIDUAL CAN WORK AT HIS OWN PACE	57%	35%	8%
THE METHOD CHECKS TO SEE THAT EACH POINT IS UNDERSTOOD BEFORE PROCEEDING TO NEXT POINT	57%	22%	21%
AN INDIVIDUAL CAN LEARN FROM HIS OWN MISTAKES WITHOUT MAKING THEM KNOWN TO THE WHOLE CLASS	18%	42%	40%
THIS METHOD CANNOT GIVE ENCOURAGEMENT LIKE A TEACHER CAN	3%	16%	81%
PROGRESS FROM ONE POINT TO NEXT IS INTERRUPTED BY HAVING TO ANSWER QUESTIONS	20%	18%	57%
AN INDIVIDUAL CANNOT ASK QUESTIONS ON HIS OWN	2%	18%	80%

CHAPTER V

SUMMARY, CONCLUSIONS, LIMITATIONS AND IMPLICATIONS

I. SUMMARY OF THE EXPERIMENT

Experimental Procedures. The purpose of this study was to gather experimental evidence that could be used as a basis for evaluating the relative effectiveness of programmed instruction as a method of teaching logarithms. The experimental population consisted of 175 girls registered in Mathematics 20. In class groups they were randomly assigned to one of two treatments: conventional classroom method of teaching or the method of programmed instruction. The topic taught to both groups was logarithms. In order that the effects of the different instructional methods on students of different abilities could be assessed, the experimental group was arbitrarily categorized into two levels, first on the basis of scholastic ability (as determined by Total SCAT scores) into HI if the score was 71 or more and LO if the score was less, and secondly, on the basis of verbal ability (as determined by Verbal SCAT scores) into HI if the stanine score was 7 or more and LO if below that.

The classes assigned to the conventional method of teaching treatment group studied the prescribed unit on logarithms in the authorized text under the direction of their regular mathematics teacher. Exercises and homework were assigned in the same manner as other units were taught.

The other classes were designated as the programmed instruction method of teaching treatment group. These classes followed the directions accompanying the programmed material and their regular mathematics teacher supervised only. The programmed material on logarithms was made available to the investigator through the co-operation of the Radar Training Centre of the Royal Canadian Air Force. This group was offered no assistance with the unit nor were they permitted to take the material out of the classroom and it was only used during the regular mathematics period. Supplementary drill exercises were available to this group to use if time permitted.

During the spring of 1965, the COOP Intermediate Algebra (Quadratics and Beyond) Form Y was administered to the experimental group as a pre-test. At the conclusion of the treatments, (two weeks later), Form Z of the same test was administered to the same group. In addition, the PROG treatment group was asked to complete a questionnaire in regard to this method of instruction.

Null hypotheses[1] were drafted from the questions[2] which the study was designed to answer. The acceptability of each of the null hypotheses was tested by carrying out a two-way analysis of variance since no initial significant difference in the two treatment groups was found. In the statistical analysis of the data, the difference

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[1]See page 51.

[2]See page 3.

between mean scores was considered statistically significant only, if the probability of observing such a difference as a result of sampling error was 0.01 or less. The responses to the questionnaire were summarized in general terms.

Results of the Statistical Analyses. The statistical analysis carried out on the data in the experiment led to the following results:

There was no significant difference between the groups in achievement with logarithms. The effect of interaction was not statistically significant. The students in level HI scores significantly higher than the students in level LO.

There was no significant difference between the groups in retention of logarithms. The effect of interaction was not statistically significant. The students in level HI scored significantly higher than students in level LO.

Findings from the Student Questionnaire. Generally, the students reacted favorably to programmed instruction as a method of teaching. Many thought that more value could be derived if a teacher was available to answer questions or add to the explanations given in the material. Most students did complain of the waste of time and the monotony of continually turning of the pages of the booklet.

II. CONCLUSIONS

On the basis of the results of the statistical analysis carried out and within the limitations of this study and in consideration of the student responses to the questionnaire, the following conclusions could be framed:

1. Programmed instruction as a method of teaching logarithms was as effective as the conventional method of teaching logarithms.

2. With regard to achievement, the effectiveness of programmed material in teaching logarithms is not related to the students' TOTAL SCAT scores nor VERBAL SCAT scores.

3. The retention of the learned materials did not differ significantly for either treatment.

4. The achievement of Level HI was significantly different from the achievement of Level LO in both treatments.

5. Students regarded the programmed instruction method as an effective method of instruction but expressed concern that boredom could set in if this method of instruction was continued for a long period of time.

6. The experiment provided validation of the programmed booklets as a method of instruction for the materials which they cover.

III. LIMITATIONS

The foregoing conclusions must be considered in the light of the following limitations of the study.

These conclusions were limited in their interpretation to the population of Mathematics 20 students in the Edmonton Separate School from which the sample was drawn. However, no attempt was made to limit the sample to any specific section of the city. Another possible limitation was the short period of time involved in the experimentation. If a longer period of time were necessary, the results could have been different. There was no attempt made to modify the method of teaching of any of the teachers. They were urged to follow the text as closely as possible.

The limitation of the testing instruments should be considered. The investigator examined the available standardized tests. It was felt that the COOP Intermediate Algebra (Quadratics and Beyond) included more questions relating to logarithms than any of the other tests examined. The retention test was taken from the school library. It was prepared by the teachers of mathematics and had been used for several years. The teachers concerned felt it would represent the scope of logarithms adequately.

The fact that the SCAT scores used were taken from the tests administered to the students two years prior to the experiment may be a limitation. However, it was felt that this was a practical way to establish a scale to determine possible success since all the

Grade IX population of Alberta was involved and that these scores were made available to the high schools concerned by the Department of Education.

IV. IMPLICATIONS

Socrates is credited with saying, "Either we shall find what we are seeking, or at least we shall free ourselves of the persuasion that we know what we do not know". It was possibly in this spirit that Nason[3] during a panel discussion on the challenge of using modern media in instruction at the Canadian Education Association convention in 1964 stated that teacher organizations should concern themselves with exploration of the medium of programmed instruction carefully in order to prevent premature commercial exploitation which might cause educators to turn away from this method of instruction before there is an opportunity to develop and utilize its potentialities for the good of education.

Among the possible benefits that may be derived from programmed instruction would be:

1) increased educational opportunities; for example, it will allow students to take courses which they might otherwise miss because of time-table conflict;
2) provision for individual needs for enrichment,
3) use as a remedial tool;

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[3] G. Nason, C. E. A. Newsletter (Canadian Education Society, ed. B. Lowery, December, 1964), p. 6.

4) use for drill and review;

5) use in teacher training; for example, programmed instruction could introduce new techniques or material and also make teachers more aware of the steps involved in learning.

One of the aspects of programmed instruction which would bear investigation is the concern of teachers about their role. Evidence offered thus far does not bear out earlier predictions that programmed instruction would replace teachers; on the contrary it may require more teacher participation. The teacher's role will of necessity have to change. The key to this changing role is the ease with which programmed materials allow a student or students to pursue a specific content area with little or no direction from the teacher. The effect of this would maximize the effectiveness of the teacher by freeing him from the routine work that now takes up so much of his time and permit more time to pursue the demanding work of guiding the process of learning.

Another aspect of programmed learning that bears further investigation is to determine the quality of available programs. Unfortunately, at present there are only a very limited number of thoroughly tested high quality of programs available.

Still another aspect of programmed instruction that requires more investigation is the "retained learning". Insofar as this investigator is concerned, no significant study has been made in this regard. How would students taught by programmed instruction

compare with students taught in the conventional classroom method one year after? two years later?

More attention must be given to the question of how well "the step by step" technique of programmed instruction can aid in concept formation. In the area of enrichment, Bale[4] stresses the lack of experimental research.

In still another direction, research should attempt to discover what combination of teacher and programmed instruction yields the most effective results. Study is also needed to consider what kind of school and classroom organizations are best suited to these combinations of teacher and programmed instruction.

From the point of view of school usage, it is also important to investigate variables outside the program; not only the teacher's role but the degree of administrative support, modifications of classroom structure, and procedures for coping with differences in individual rates of learning.

The results of such studies will contribute to our scanty knowledge about the impact of programmed instruction on the classroom. We must keep in mind that it was never possible for an elementary school or a secondary school or a university to offer all that needs to be learned, but in the pace of the "explosion of knowledge" we can scarcely delude ourselves any longer. The problem is

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[4]Chapter II, p. 30.

not just the impossibility of absorbing or mastering immense quantities of information, but that much of the knowledge, the skill, or the insights are possible only as persons mature.

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APPENDIX

SCORES FOR ALL STUDENTS

Beginning on the following page, the scores obtained by the CON group (taught logarithms by the conventional classroom method) are listed.

The symbols heading the columns are to be interpreted as follows:

ID	(Column I):	Identification Number
PRE	(Column 2):	Cooperative Intermediate Algebra Test (Quadratics and Beyond) Form Y (scaled) score.
POST	(Column 3):	Cooperative Intermediate Algebra Test (Quadratics and Beyond) Form Z (scaled) score.
TOT	(Column 4):	Total SCAT Ability (percentile) score
VERB	(Column 5):	Verbal SCAT (stanine) score.
RET	(Column 6):	Logarithm Retention (raw) score.

ID	PRE	POST	TOT	VERB	RET
001	62	64	95	7	5
002	56	61	43	3	6
003	55	58	62	5	1
004	59	58	38	4	7
005	51	40	25	5	0
006	50	59	64	5	5
007	60	63	72	6	2
008	62	58	45	7	6
009	55	58	64	5	6
110	53	58	75	6	5
012	60	63	50	4	4
013	66	64	92	7	7
014	63	64	75	9	8
015	52	54	42	5	6
016	66	68	92	8	8
017	62	64	76	7	8
018	52	56	54	6	4
019	66	64	99	9	6
020	50	53	60	6	2
021	42	53	66	5	4
022	52	55	85	7	5
023	42	55	72	7	3
024	46	51	56	5	0
025	59	60	80	6	2

ID	PRE	POST	TOT	VERB	RET
026	60	63	99	9	3
027	58	59	80	7	8
028	49	53	43	5	3
029	46	55	92	8	3
030	38	47	21	3	0
031	56	63	93	8	6
032	51	57	64	6	1
033	60	56	66	5	2
034	51	49	54	5	1
035	55	59	84	7	7
036	48	49	54	5	3
037	52	48	78	7	4
038	53	60	58	5	1
039	54	44	56	5	2
040	57	57	82	7	3
041	57	57	82	7	3
042	57	56	85	9	3
043	58	60	87	6	0
044	53	58	84	8	5
045	50	55	76	7	3
046	49	52	60	6	1
047	60	60	89	6	8
048	48	54	41	5	5
049	47	49	26	5	5
050	57	58	49	5	4

ID	PRE	POST	TOT	VERB	RET
051	53	57	70	5	6
052	39	51	79	8	1
053	49	54	52	5	4
054	47	47	42	5	4
055	62	56	87	7	6
056	53	56	68	6	8
057	57	55	74	7	7
058	61	60	34	3	7
059	55	57	80	6	3
060	62	65	85	6	8
061	60	59	62	5	4
062	60	60	78	8	8
063	58	56	49	4	8
064	53	55	68	6	2
065	58	58	72	6	6
066	61	54	88	8	4
067	59	61	78	7	8
068	62	60	65	6	7
069	57	44	62	6	4
070	60	51	60	5	5
071	54	53	56	5	4
072	52	56	84	8	3
073	48	55	40	4	1
074	48	44	51	4	7
075	55	56	47	4	3

ID	PRE	POST	TOT	VERB	RET
076	58	50	66	7	7
077	56	63	72	7	5
078	62	59	56	5	8
079	62	57	84	8	1
080	55	59	84	8	4
081	51	49	45	6	0
082	51	59	44	3	7
083	58	60	78	6	7
084	59	63	48	5	7
085	54	58	87	7	3
086	57	58	56	6	7
087	64	63	96	8	8
088	55	59	68	6	6
089	55	58	70	5	4
090	57	49	28	3	3
091	46	49	34	5	4
092	55	57	56	5	6
093	46	53	64	6	3
094	55	56	45	4	6
095	54	61	35	3	5
096	47	52	45	5	1

Below, the scores obtained by the PROG group (taught logarithms by programmed instruction) are listed:

ID	PRE	POST	TOT	VERB	RET
097	58	58	62	5	3
098	61	63	75	5	2
099	54	56	96	9	3
100	54	56	75	7	1
101	51	60	65	7	2
102	52	53	64	6	7
103	51	54	84	6	1
104	56	55	75	7	4
105	49	47	47	5	4
106	54	56	66	5	3
107	47	56	38	4	2
108	54	55	48	4	1
109	62	63	78	6	6
110	50	50	70	5	2
111	61	62	80	5	5
112	58	59	95	5	5
113	48	55	80	7	6
114	50	58	78	7	5
115	50	52	49	6	1
116	55	61	84	4	1
117	54	55	93	7	6
118	49	57	66	6	2
119	52	56	78	5	1
120	47	48	49	5	0

ID	PRE	POST	TOT	VERB	RET
121	53	58	60	5	1
122	44	54	56	5	6
123	51	60	85	6	6
124	61	64	98	9	5
125	52	58	82	7	5
126	59	60	85	6	7
127	63	60	85	7	9
128	57	52	82	7	3
129	54	56	70	6	3
130	58	58	36	4	8
131	47	50	45	4	2
132	64	63	89	7	9
133	56	54	66	5	2
134	56	57	72	6	7
135	44	52	62	9	1
136	59	60	58	5	7
137	48	52	39	4	0
138	58	54	68	6	7
139	50	47	56	3	3
140	53	50	27	2	0
141	63	66	99	9	7
142	60	60	98	8	9
143	58	56	64	5	4
144	53	56	13	3	3
145	65	65	98	9	4

ID	PRE	POST	TOT	VERB	RET
146	57	56	60	7	3
147	60	59	97	9	4
148	61	56	78	6	2
149	58	59	85	7	8
150	60	60	97	9	8
151	58	61	60	5	3
152	66	65	97	9	7
153	54	54	61	6	1
154	51	51	64	5	5
155	58	56	49	5	7
156	53	54	72	5	6
157	61	62	60	5	5
158	48	50	84	8	4
159	62	58	51	4	2
160	58	62	98	9	8
161	61	62	93	9	4
162	56	58	85	6	7
163	55	58	75	6	1
164	56	55	72	7	8
165	60	62	96	8	8
166	61	61	98	9	9
167	58	60	92	8	6
168	57	60	87	6	8
169	54	54	95	9	6

ID	PRE	POST	TOT	VERB	RET
170	66	67	99	9	9
171	58	59	78	5	6
172	61	61	97	8	9
173	58	57	82	6	2
174	63	63	97	7	2
175	61	64	99	9	8

CHI SQUARE TEST ON CELL FREQUENCIES

(Adaptation from Ferguson, p. 169 Table, p. 309)

BASED ON TOTAL SCAT SCORE:

	HI	LO	
CON	40	56	96
PROG	32	47	79
	72	103	175

$$X^2 = \frac{175(32\times56 - 40\times47)^2}{79\times96\times72\times103}$$

$$= \underline{0.03} \quad \text{(not significant)}$$

BASED ON VERBAL SCAT SCORE:

	HI	LO	
CON	34	62	96
PROG	34	45	79
	68	107	175

$$X^2 = \frac{175(34\times62 - 34\times45)^2}{96\times79\times68\times107}$$

$$= \underline{1.06} \quad \text{(not significant)}$$

df = 1

$X^2_{.10}(\text{df } 1) = 2.71$

$X^2_{.01}(\text{df } 1) = 6.64$